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Session 2, Topic 2

Elasmobranchs of the Vanua o VotuaQoliqoli – a Baseline Assessment of Sharks and Rays

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Abstract

The demarcation of a potential shark and ray nursery area in the Ba Estuary was prepared in accordance with Activity 1.1.1.2 of the Global Environment Facility (GEF) funded Fijian Government's Ridge to Reef (R2R) project, implemented by the United Nations Development Programme (UNDP) and the Ministry of Waterways and Environment. As part of this component of the Fiji R2R project, fishery-independent surveys of elasmobranch fauna were undertaken in the Ba Estuary in Viti Levu by the University of the South Pacific's School of Marine Studies and the Institute of Applied Sciences over a period of 113 days from December 2015 to July 2019 and were comprised of 361 bottom-set gillnet and longline deployments at multiple sites in the estuary. Key findings encompassed the discovery of four shark and two ray species in the surveys. Three further elasmobranch species were observed sporadically, but not captured in the surveys. Of these nine species, three are listed as Critically Endangered, four as Vulnerable and two as Near Threatened on the International Union for the Conservation of Nature (IUCN) Red List. Increased elasmobranch abundance and an elevated proportion of neonates occurred from November to February, most likely the birthing season for the encountered species. Further, a critical area with high catch of juveniles in the center of the estuary was demarcated and recommended as highest priority area for management. This paper supports the Ba Estuary as a likely and valuable target for elasmobranch conservation.

Recommendations:

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The R2R Technical Consultation is invited to discuss the paper and provide suggestions on the application of methodology employed for assessing sharks and rays. The discussion could also focused on the implications of results for future R2R investments and planning, particularly with respect to the management of the Ba Estuary to conserve elasmobranch.

Elasmobranchs of the Vanua o VotuaQoliqoli – a Baseline Assessment of Sharks and Rays

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1. Introduction

Sharks and rays are facing significant reductions in population sizes in recent times, making it a necessity to better understand their biology and ecology. Multiple human-driven factors like habitat loss, fishing pressure and climate change are threatening a large amount of the more than 1,250 recorded elasmobranch species (Dulvy et al., 2014, 2017; Ferretti et al., 2010). Sharks and rays are considered keystone species and due to low annual reproductive output, late age of sexual maturity, slow growth rates and long life spans, rigorous efforts are required to effectively manage populations of sharks and rays (Dulvy et al., 2014, 2017; Ferretti et al., 2010; Heithaus et al., 2008). Sharks and rays are targeted in a wide range of fisheries for multiple products including meat, fins, gills and teeth. Incidental catches (bycatch) are also frequent, including in artisanal fisheries.

Conservation efforts for elasmobranchs require a clear understanding of the ecological processes they support and depend on. Many species exhibit philopatry, whereby individuals often return to or remain in specific locations for mating, parturition and maturation, making certain areas essential for population survival (Chapman et al., 2015; Hueter et al., 2005; Tillett et al., 2012). Elasmobranch species which exhibit philopatry within coastal embayments and estuaries are subject to a plethora of threats both natural and anthropogenic. Estuaries in particular face heavy pressures, such as fishing, an increase in coastal development, declining water quality and habitat loss owing to their close proximity to human populations (Lotze et al., 2006). It has been suggested that several shark species use estuaries as nursery areas. They are hence considered critical habitats and their identification is key to understanding elasmobranch ecology and improving current management approaches.

To support the identification of a critical habitat and potential nursery area in the Ba Estuary, Fiji Islands, this report compiles the results from fishery-independent surveys. The results serve as the basis for the demarcation of areas critical for protection within the Ba Estuary and for coastal management recommendations with special emphasis on potential locally managed marine areas (LMMAs).

2. The Ba Estuary

The Ba River Delta (Figure 1) is located on the Northwestern or leeward side of Fiji's largest island Viti Levu and supports one of the country's largest contiguous stands of mangroves with a total area of approximately 400 square kilometers, of which the majority is located on the large river mouths (Secretariat of the Pacific Regional Environment Programme, 2007).

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The study site encompasses an area of approximately 29 square kilometres with a depth range from one meter along the fringes of the mangroves to five meters along the seaward boundary where the inshore mud and sand flats drop off to the continental shelf. The western most boundary lies along Natogo Creek which flows into the Karavi Bay and the eastern most end is bound by Bulu Creek, a distance of approximately thirteen kilometers. The average distance from the land-sea interface to the drop off is two kilometers and include a diverse array of habitats such as mangroves, shorelines, estuaries, lagoons and reefs.

The substrate comprises of bare rock, mud and sand, which supports a variety of seagrass including *Halophilaovalis* and algal beds dominated by *Dictyota* species. The Ba Estuary has been documented as supporting a high fish diversity and a high crustacean and mollusk productivity (Sykes et al., 2018).

3. Objective

The aim of this report is to demarcate a possible elasmobranch (sharks and rays) conservation area for the Ba Estuary. The objectives of the report are to:

- Investigate and quantify the distribution and abundance of elasmobranch species in the Ba Estuary.
- Identify and demarcate potentially important shark and ray nursery areas and appropriate conservation tools for enhanced protected LMMA according to IUCN protected area category VI.

4. Methodology

4.1 Sampling Methods

Fishery-independent surveys were undertaken over a period of 113 days from December 2015 to July 2019 and were comprised of 361 bottom-set gillnet and longline deployments across the estuary. The sampling area was selected on the advice of local fishermen and a pilot study by one of the authors (T. Vierus). Sampling times were between 5pm and 2am. Up to two gillnets (100 m length and 3 m width, ~10 cm mesh size) were deployed simultaneously with a soak time of 1–6 hrs. To minimize animal stress and mortality, gillnets were regularly checked in intervals of 15–25 min. When feasible, a longline (75 m) with 27 hooks was additionally deployed. Distance between gangions attached to the floater line varied from 2.4 to 2.8 m. Gangion length ranged between 0.6 and 3 m, with the last 0.5 m consisting of 1.5 mm steel wire and a baited 13” circle hook. A Garmin e-trex 20 model GPS was utilized to record site locations. See Appendix A1 for composition of bycatch.

4.2 Shark Handling

Captured individuals were freed, processed and released back into the water on the opposite end of the boat. Processing involved recording species when possible, sex, umbilical scar condition and total length. The umbilical scar condition was categorized based on the degree of healing; open, semi-healed, healed. Open and semi-healed umbilical scars are characteristic for the neonate period with a duration of approximately 15 days until healed. Healed scars are indicative of an age more than 15 days and these specimens are classified as young-of-the-year (Duncan and Holland, 2006).

5. Results

5.1 Catch Composition

Between December 2015 and July 2019, a total of 361 deployments (330 gillnet and 31 longline) were conducted totaling 587 hours of fishing distributed across seasons (Figure 2A). Total elasmobranch catch per unit effort (CPUE) was 0.38 per hour. CPUE was highest from November to February and April to June (Table 1; but note the comparably small number of effort in April, May, July and August shown in Figure 2A).

The fishery-independent survey led to the capture of 207 sharks consisting of four shark species (Table 2): scalloped hammerhead shark (*Sphyrna lewini*; N = 97), blacktip shark (*Carcharhinuslimbatus*; N = 89), great hammerhead shark (*Sphyrna mokarran*; N = 14), bull shark (*Carcharhinusleucas*; N = 7), and 18 rays consisting of two ray species (Table 2): ocellated eagle ray (*Aetobatusocellatus*; N = 13), and pink whipray (*Pateobatusfai*; N = 5). Sporadic observations in the Ba Estuary of one of the authors (A. Paris) documented the occurrence of at least one more shark species: tawny nurse shark (*Nebriusferrugineus*; N = 2); and two more ray species: reef manta ray (*Manta alfredi*; N = 8) and bottlenose wedgefish (*Rhynchobatusaustraliae*; N = 2).

5.2 Biological Data

The two most common elasmobranch species encountered during the fishery-independent survey were the scalloped hammerhead shark *S. lewini* (N = 97) and the blacktip shark *C. limbatus* (N = 89). With mean sizes of 51.6 cm and 66.1 cm, respectively (Table 2), captured sharks were either neonate or young-of-the-year. The great hammerhead individuals encountered during this study (*S. mokarran*, N = 14) exhibited a mean length of 76.5 cm, whereas the seven bull sharks (*C. leucas*) measured a mean length of 88.1 cm. The male: female ratio of the blacktip shark and the scalloped hammerhead shark was about 1:1, while female great hammerheads outnumbered males with a male to female ratio of 0.4:1 (but note the small sample). Overall, 69% of successful umbilical scar assessments of captured sharks demonstrated open or semi-healed scars, indicating recent birth for the majority of those individuals. The proportion of open umbilical scars was especially high from November to February (Figure 2BC).

5.3 Spatial Distribution of Elasmobranchs

Analyzing total elasmobranch CPUE spatially (as CPUE per grid cell of 1.3 km^2; see Figure 3) revealed high abundance particularly in the center area of the Ba Estuary close to the river mouth, extending along the coast to the West.

Spatial CPUE data was used to designate a highest priority area which could be recommended as target area for management interventions. Figure 4 shows the minimum rectangle which includes all grid cells with elasmobranch CPUE ≥ 1 from Figure 3. Its size is approximately 18.2 km^2 and it is described by the following coordinates in decimal degree: longitude 177.6136 to 177.6864 and latitude -17.4344 to -17.4136.

6. Discussion

6.1 Elasmobranchs of the Ba Estuary

The study evaluated the catch composition of a fishery-independent survey of elasmobranch species in the Ba Estuary and calculated corresponding total CPUE which was 0.38 per hour. Increased abundance of elasmobranchs was observed from November to February (Table 1) when focussing on those months with considerable sampling effort (Figure 2A). These months also tended to be the months with a high proportion of recently born sharks (open or semi-healed umbilical scar). Spatial CPUE data demarcated an area with elevated elasmobranch occurrence in the center of the estuary (Figure 4), consistent with results from a subset of the data previously reported by (Vierus et al., 2018).

6.2 Elasmobranch Philopatry

The consistent sightings, captures, mean lengths and umbilical scar conditions of these sharks and the scientific studies that took place in the area as well as in the broader region strongly indicate that the Ba Estuary serves first as a birthing ground and then as a subsequent nursery area for young sharks. As rather shallow, sheltered and highly biologically productive environments, bay habitats offer protection from larger sharks and/or offer ample food opportunities for individuals in the first months of their lives (Heupel et al., 2007).

The most dominant elasmobranch species in the Ba Estuary were the scalloped hammerhead shark (*S. lewini*), the blacktip shark (*C. limbatus*) and the great hammerhead shark (*S. mokarran*), all of which have been shown to exhibit regional philopatry in other places (Chapman et al., 2015; Guttridge et al., 2017). This behavior should spark strong effort by researchers and policy-makers to identify and subsequently protect these areas that play a vital part in the sharks' life-cycle. Similarly, bull sharks (*C. leucas*), which were captured near the Ba River mouth and previously observed more upstream, also exhibit regional philopatry (Tillett et al., 2012). Potentially, adult females utilize the Ba River year after year to give birth to their offspring before returning into deeper waters.

6.3 Critical Elasmobranch Areas

It is highly probable that the Ba Estuary plays a critical role in the early-life stages of at least four of the occurring sharks (scalloped and great hammerhead, blacktip, and bull shark). While individuals have been caught throughout the sampling area, the highest CPUE was recorded around the center and center-Westward section of the study area (Figure 3). This subsection of the estuary can with moderate-to-high confidence already be recommended for intensified management.

The demarcation of the priority 2 area follows the rationale to extend the highest-priority area towards the river mouth and mangroves. The reasons for selecting this area are (i) repeated elasmobranch catches (although at lower CPUEs, see Figure 3) including all catches of bull sharks (*C. leucas*) in this study, (ii) close proximity to the highest-priority area with highest catch rates and (iii) the generally high productivity and diversity of near-shore areas, estuarine mixing zones and mangrove habitats which are likely essential to species at higher trophic levels like elasmobranchs. Indeed, the nearshore mangroves and mudflats of the Ba Estuary have been attested to be high fish diversity and crustacean and mollusc productivity areas (Sykes et al., 2018, p. 50). The size of the priority 2 area was matched to the size of the highest-priority area and is also approximately 18.2 km² and described by the following coordinates in decimal degree: longitude 177.6136 to 177.6864 and latitude to -17.4552 to -17.4344.

6.4 Elasmobranch Conservation

Both hammerhead shark species (*S. lewini* and *S. mokarran*) frequently encountered and captured in the Ba Estuary are classified as Critically Endangered on the Red List of Threatened Species (IUCN, 2019). The blacktip shark (*C. limbatus*), the second most abundant shark during the sampling period, and the bull shark (*C. leucas*) are listed as Near Threatened. Four of the sporadically documented species are listed as Vulnerable; the ocellated eagle ray (*Aetobatusocellatus*), the pink whipray (*Pateobatusfai*), the reef manta (*Manta alfredi*) and the tawny nurse shark (*Nebriusferrugineus*). Of particular significance is the Critically Endangered bottlenose wedgefish (*Rhychobatusaustraliae*) which was encountered on two occasions. All listings (see Appendix A2) highlight the urgency of protecting the shark and ray species. The current high fishing pressure leads to unsustainable catch rates, which by far exceed the natural capability of these predators to reproduce quick enough and maintain healthy populations.

6.5 Management Implications and Recommendations

In accordance with the IUCN Category VI, we propose the following possibilities for the Ba Estuary with the aim of maintaining sustainable resource extraction while minimizing elasmobranch mortality. Note that the term "demarcated area" preferably refers to:-

(i) the highest-priority area and the priority 2 area jointly as shown in Figure 4, but may refer, with decreasing preference,
(ii) to the highest-priority area alone, or
(iii) the priority 2 area alone, in case the preferred area is compromised by stakeholder requirements or policy trade-offs.

Possibility 1: Partial ban on gillnet fishing in the demarcated area during the peak of the parturition period (November to February).
Possibility 2: Partial ban on gillnet fishing in the Ba Estuary during the peak of the parturition period (November to February).
Possibility 3: Complete ban on gillnet fishing in the demarcated area throughout the year.
Possibility 4: Complete ban on gillnet fishing in the Ba Estuary throughout the year.

The protection of the recently listed Critically Endangered bottlenose wedgefish (*Rhychobatusaustraliae*) will need immediate and intensive management actions. There have been few recorded sightings of the species and it is strongly recommend a gazetted no-go, no-take boundary be set up.

Generally, it is strongly recommended the precautionary principle be applied in the Ba Estuary with further complimentary scientific studies into remaining elasmobranch numbers, population dynamics, breeding success rates and potential threats in the area, including bycatch monitoring.

6.6 Potential Challenges and Issues

The establishment of LMMAs in Fiji are considered to be a tool for integrated ocean management and not a final or universal solution (Govan et al., 2011). Simply safeguarding an area from one type of threat (e.g., overfishing) does not nullify other threats such as pollution or ecosystem degradation through extractive industries. Declaring an area as locally managed will inadvertently affect the local communities who rely on the Ba Estuary for subsistence. Therefore, the input of the traditional custodians of the area in the consultative process is vital. A transparent and inclusive process with all relevant stakeholders would provide the traditional fishing rights owners a clear understanding of changes and limitations created by the establishment of the LMMA, allowing for better monitoring and enforcement (Clarke and Jupiter, 2010). A management framework tailored to the specific requirements of the area should be based on scientific research, as presented here, and would subsequently improve the decision-making process more particularly on what specific activities to be regulated. Within the framework of the LMMA, honorary fish wardens need to be better equipped to effectively monitor illegal and unregulated fishing, poaching and bycatch. Fish wardens should also be trained on proper handling techniques as well as live release procedures.

7. Conclusion

In total, 207 sharks and 18 rays were caught consisting of six different elasmobranch species (four and two, respectively). Two of the present shark species are listed as Critically Endangered on IUCN's Red List of Threatened Species (scalloped and great hammerhead shark) and the remaining two sharks (bull and blacktip shark) and ray species (ocellated eagle ray and pink whipray) are listed as Vulnerable (IUCN, 2019). Three sporadically encountered species in the bay, the reef manta and the tawny nurse shark, are listed as Vulnerable and the bottlenose wedgefish (encountered on two occasions) as Critically Endangered.

The fact that the shark catch consisted of predominantly newborn sharks according to umbilical scar condition (most likely less than two weeks old) indicates the importance of this area with a high probability that it serves as a parturition area and nursery ground. Highest densities of newborn sharks were observed in the center part of the delta (Figure 3) during the summer months of November to February (Table 1), a time period that overlaps with data from the Rewa Delta (Marie et al., 2017), as well as from Australia (September to February; Miller et al., 2013). Based on this, we demarcated a highest-priority and priority 2 area for protection as well as respective timeframes for gillnets fishing closures.

Based on the data collected for this report, there is little doubt that the Ba Estuary serves as an important habitat for several elasmobranch species. While the exact function of the Ba area in regard to the lifecycle of the observed elasmobranchs remains to be scientifically investigated, a precautionary management approach dictates that LMMAs should be extended to the Ba Estuary to protect these animals. Current bycatch levels are high and additional external stressors, such as habitat destruction due to mining activities, threaten the health and continuous existence of the local shark and ray populations. Without adequate action, this may eventually lead to local extinction of the present species with potentially severe ecological consequences for the Ba River and estuary, but also for elasmobranch populations more globally.

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Tables and Figures

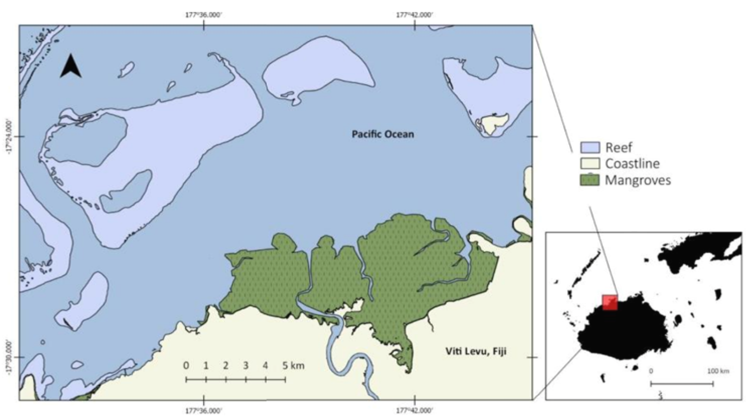

Figure 1. Map of the Ba Estuary in north-western Viti Levu, Fiji Islands. Adapted from Vierus et al. (2018)

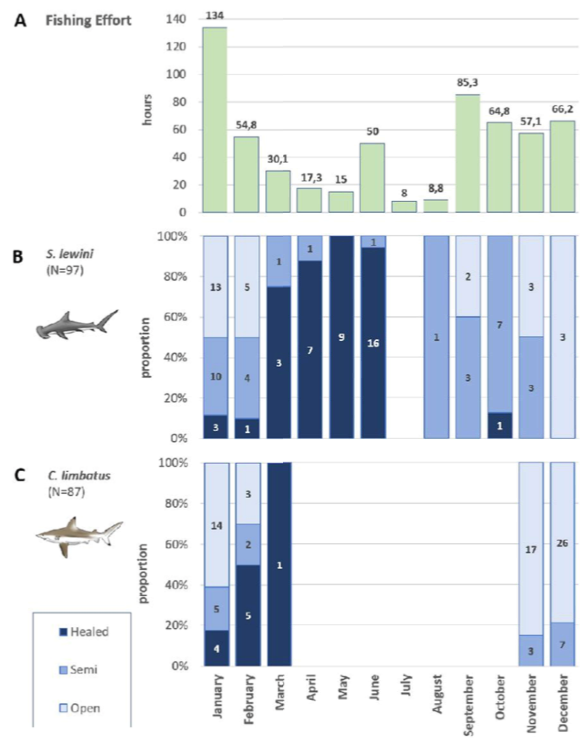

Figure 2. Pooled monthly fishing effort (A) and umbilical scar condition (open: light blue; semi-healed: blue, closed: dark blue) for the two most frequently caught species (B) *S. lewini* (scars identified in N = 97 individuals), and (C) *C. limbatus* (scars identified in N = 87 individuals).

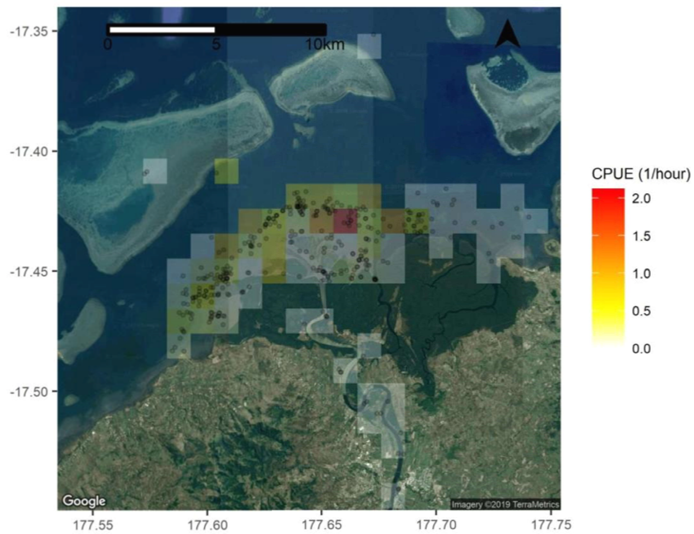

Figure 3. Spatial distribution of elasmobranchs (all shark and ray species pooled). One point represents one sampling deployment. Coloring intensity of a grid cell reflects CPUE for all sampling deployments within the cell (approximately 1.3 km²). No grid cells are shown for areas where no surveying occurred. Axis labels are coordinates in decimal degrees.

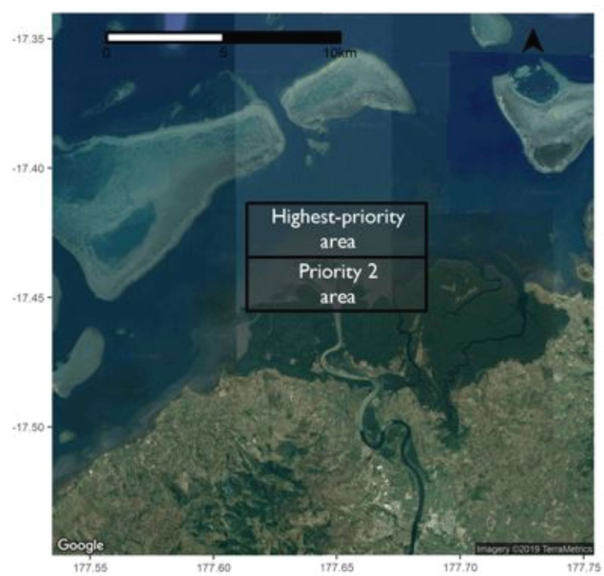

Figure 4: Highest-priority and priority 2 area for elasmobranch conservation in the Ba Estuary.

Table 1. Elasmobranch CPUE in 1/hour, aggregated by month

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov	Dec
Mean CPUE	0.49	0.46	0.22	0.46	0.67	0.40	0.12	0.23	0.12	0.19	0.47	0.60

Table 2. Overview of elasmobranch species caught in the Ba Estuary and information on sex, length and umbilical scar condition for those where measurement was possible.

Species	N	Sex		Length				Umbilical scar condition		
		male	female	mean	SD	min.	max.	open	semi-healed	healed
S. lewini	97	50	47	51.6	4.9	37	61.8	26	31	40
C. limbatus	89	45	43	66.1	3.5	54.3	76.4	60	17	10
S. mokarran	14	4	9	76.5	3	72.3	81.5	-	4	9
C. leucas	7	3	4	88.1	12	81	115	5	1	1
A. ocellatus	13	2	3	49.6	13.9	29	62	-	-	2
P. fai	5	0	4	103.3	23.6	85	130	-	-	3